Forest Health Protection

Northeastern California Shared Service Area

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Forest Health Survey of Northeastern California Aspen

FHP Report # NE-SPR-12-01

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BACKGROUND

Concern for the health of California's quaking aspen (*Populus tremuloides*) habitat has increased in recent years due to heavy wild ungulate and domestic livestock browsing, competition from conifers and other vegetation in the absence of fire, the impacts of drought and the potential

negative impacts of climate change. In response, land managers are taking inventory of California's aspen resources and identifying the magnitude of these threats. These inventories have thus far included assessments of aspen regeneration, conifer encroachment and animal browsing as indicators of aspen health. Restoration treatments have also been implemented to rejuvenate and protect individual aspen stands. These include removal of competing conifers, fencing, prescribed burning and/or a combination of treatments. Recent California aspen studies have examined regeneration response to conifer removal treatments (Jones et al. 2005, Shepperd et al. 2006), simulated browsing (Jones et al. 2009), and white fir competition (Pierce and Taylor 2010). To date, no inventories or studies in California have assessed the impacts of native insects and diseases to aspen health or their responses to various restoration treatments.

Aspen stand acreage and health throughout the west has declined over the past 125+ years. Two factors are most commonly cited as contributing to this decline are changes in fire regimes since European settlement and heavy ungulate browsing leading to inadequate regeneration (Bartos and Campbell 1998, Sheppard et al. 2006). In the Warner Mountains of northeastern (NE) California, the number of acres with aspen cover has declined by 24% since 1946 (Di Orio et al. 2005) and declining stand conditions are common on the Eagle Lake Ranger District, Lassen National Forest due to conifer encroachment and poor regeneration (Jones et al. 2005).

In 2004, aspen stands throughout Colorado experienced a die-off event termed "sudden aspen decline" (SAD). Affected stands experienced rapid mortality of both overstory stems and regeneration but no specific biotic agent could be identified as the cause. This die-off event followed a period of severe drought from 2000 to 2004 that was ultimately implicated as the primary mortality agent. One study revealed that aspen growing on sites that experienced greater moisture deficits during the peak of the drought suffered greater levels of decline (Worrall et al. 2010). Other investigations found that moisture stressed aspen became more vulnerable to secondary insects and disease agents that typically cause insignificant damage under normal conditions (Worrall et al. 2008). Another study indicated that the recent drought-driven die-off resulted from hydraulic impairment of distal branches and roots (Anderegg et al 2011). This die-off event resulted in an effort by Forest Health Protection to document aspen damage/decline agents in other parts of the west.

In 2009, Region 5 Forest Health Protection, NE California Shared Service Area, was provided an opportunity to collect baseline data on aspen damage/decline agents throughout NE California as part of the west-wide monitoring effort. In order to cover a wide range of aspen habitats, permanent plots were established in selected aspen stands in Modoc, Lassen, Plumas and Tahoe National Forests and Surprise Valley, Alturas and Eagle Lake Bureau of Land Management (BLM) Resource Areas (Figure 1). The California effort complimented surveys that assessed the impacts of aspen damage/decline agents in Nevada, Utah, southern Idaho and Wyoming (USFS Region 4) in 2006 and 2007, and Montana and northern Idaho (USFS Region 1) in 2008. This baseline data will provide the opportunity to monitor changes through time in aspen stand dynamics and impacts and responses to disturbance agents, including climate change.

This survey also contributed data to the Western Wildland Environmental Threat Assessment Center (WWETAC) Aspen Decline Rapid Threat Assessment Project. This ongoing project attempts to define the state of aspen health by coordinating aspen health datasets throughout various regions in the western United States.
(http://www.fs.fed.us/wwetac/projects/jacobi2.html).

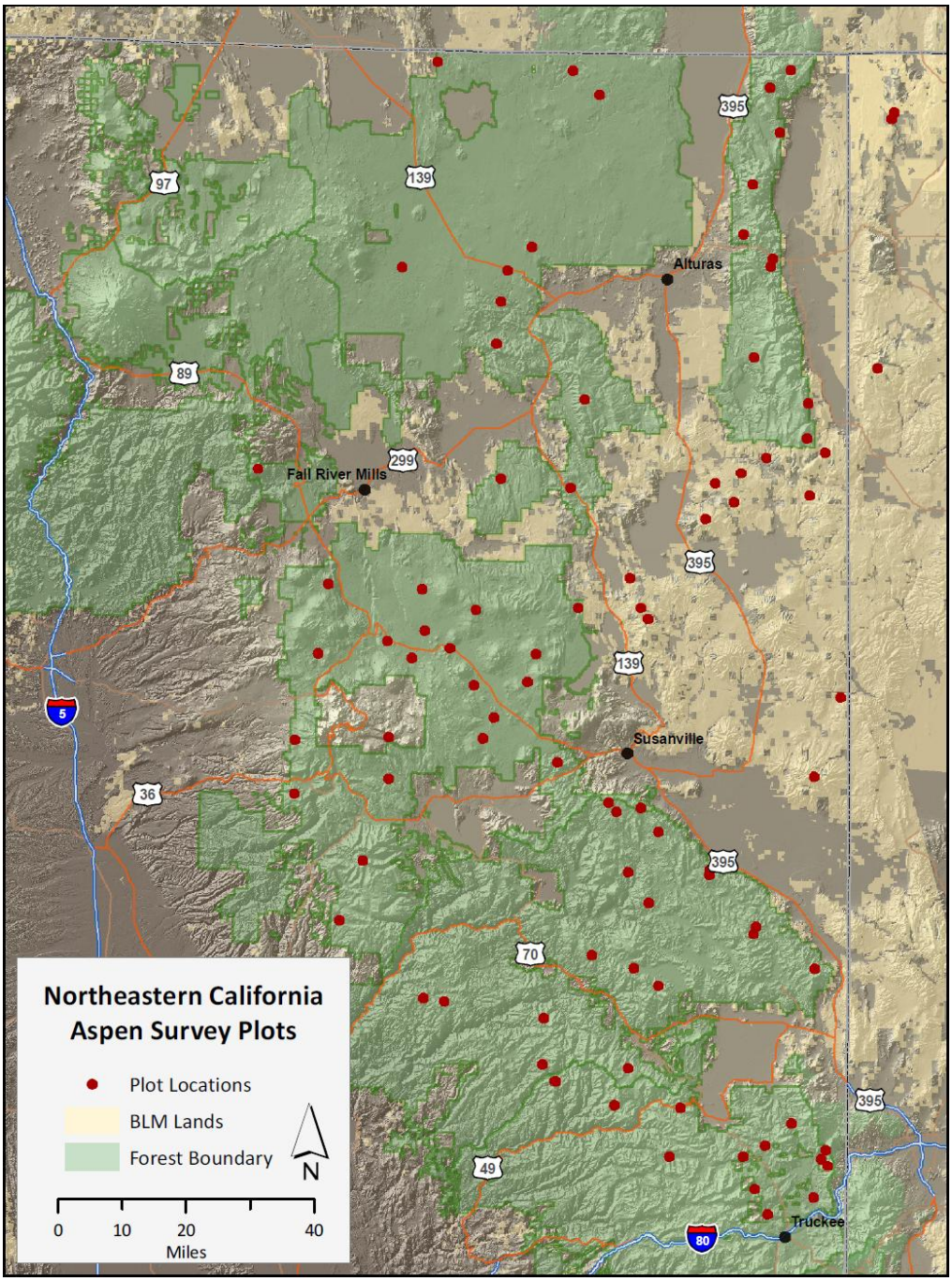

Figure 1. Northeastern California aspen survey plot locations

METHODS

The methods utilized for the NE California aspen survey were developed by Forest Health Protection staff in Region 1 (Steed and Kearns 2010) with few modifications.

Aspen stands were selected to cover a broad range across NE California using existing GIS layers and hand drawn maps. Stand selection also considered stand size, proximity to roads, land manager preference, and the inclusion of treated stands (conifer removal, recent fire, and/or fencing). Preference was generally given to larger stands to ensure enough mature live stems

were available for insect and disease evaluations. Stands that did not have enough mature live stems present were dropped and a predetermined alternate was surveyed.

Table 1. Ownership of sampled aspen stands

National Forests and Resource Areas	# of stands surveyed
Modoc NF	22
Lassen NF	25
Plumas NF	17
Tahoe NF	13
Surprise RA	5
Alturas RA	5
Eagle Lake RA	4
TOTAL	91

Data was collected from June through August 2009 throughout NE California on US Forest Service (USFS) and Bureau of Land Management (BLM) lands (Table 1 and Figure 1). Plots covered a wide range of aspen types from the wetter upper west side of the Sierra Nevada to drier eastside mixed conifer and yellow pine types of the eastern Sierras, Southern Cascades and Modoc Plateau. Plots were also established within high desert areas of the Modoc Plateau associated with western juniper (*Juniperus occidentalis*), curl-leaf mountain mahogany (*Cercocarpus ledifolius*) and/or sagebrush (*Artemisia* spp.).

In addition to covering a wide range of aspen habitats, plots were established in stands that recently had conifers removed (n=13) or were burned by recent wildfires (n=3). When treated or burned stands were selected, an equal number of untreated stands were sampled in the same general area for comparison (if available). Plots ranged in elevation from 4235 to 7437 feet with an average slope of 10% (range 0 – 55). Plots were located on all aspects with the majority occurring on north, northeast, and east facing slopes.

91 permanent plots were established consisting of a 26.2 foot radius (1/20th acre) circular plot containing three nested 6.8’ radius (1/300th acre) subplots. Subplots were established within each 1/20th acre plot at 0, 120 and 240 degrees and 13.1’ from plot center (Figure 2). Plots were randomly selected within the stands but had to meet the minimum requirement of having two live aspen trees ≥ 5.0” diameter breast height (dbh) located within the 1/20th acre plot. All plot centers were recorded using a global positioning system (GPS, NAD83) and monumented with a metal tee post. Site data collected for each plot included slope position, aspect and elevation. Stand level descriptions were subjective and included any association with riparian zones, conifer and non-aspen hardwood competition, presence/absence of animal browsing, stand direction (retreating, expanding or stable), successional status (successional or stable), and an overall risk rating (low, moderate, high). Risk was defined as the chance that a stand could die out. Each stand was also surveyed for the simple presence of damage agents in order to create a comprehensive list. Photos were taken from plot center in cardinal directions to capture stand attributes.

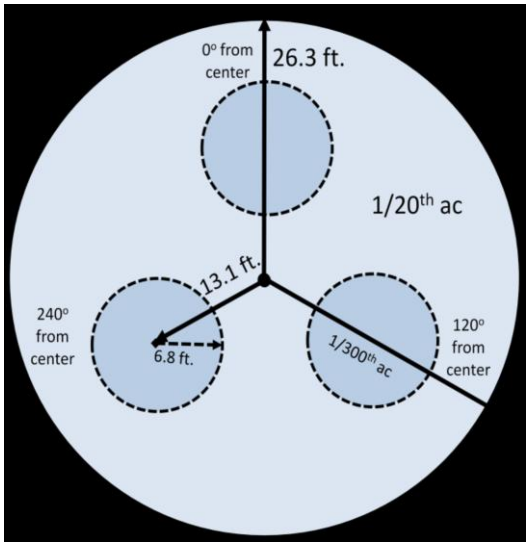

Figure 2: Configuration of plot and subplots used to determine condition of aspen stands in the northeastern California.

Within the 1/20th acre plot, all species of trees ≥ 5.0” dbh were tagged, facing plot center, starting at north and sequentially clockwise. Each of the tagged trees was then evaluated from all directions.

For aspen trees, dbh, crown class (dominant, co-dominant, etc.), level of dieback (<33%, 33-66%, >66%), tree condition (live, recent dead, older dead), and presence of potentially damaging agents and their corresponding severity were recorded. Damage agents were identified by characteristic physical evidence. Damage severity was rated as low, moderate, or high for the top three cambium or foliage damaging agents that were likely to affect future tree survival and growth. No severity ratings were given to agents such as trunk rots, broken tops, or root decays. Data collected for individual conifers and non-aspen hardwoods included species, dbh, crown class, and tree condition.

Data for trees < 5.0" dbh was collected within the three nested 1/300th acre subplots. Species, crown class, dbh, level of dieback, condition, and damage agents and severity were recorded for all 2.0 to 4.9" dbh aspen stems, defined as saplings. Non-aspen saplings only had species, dbh, crown class and condition recorded. All saplings were identified with the number of the regeneration plot (0, 120 or 240) in place of a tag number.

All stems < 2.0" dbh, defined as seedlings, were counted and the three most damaging agents and their corresponding severities were evaluated for aspen seedlings only.

(Definitions for all data are found in Appendix A)

RESULTS

Plot attributes

Aspen was the primary tree species in 87% of the plots and white fir (*Abies concolor*) was the primary species in 5% of the plots. Ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*), lodgepole pine (*Pinus contorta*), red fir (*Abies magnifica*) and black cottonwood (*Populus trichocarpa*) were each dominant and/or co-dominant on at least one plot. Nineteen tree species were recorded as secondary on survey plots (Table 2) and only 8.8% of plots had aspen as the only species.

Table 2. Secondary trees species recorded in survey plots

Secondary tree species	% of plots
White fir	36
Jeffrey pine	27
Western juniper	26
Lodgepole pine	24
Ponderosa pine	23
Red fir	18
Incense cedar	14
Mountain mahogany	7
Willow species	5
Western white pine	3
Alder species	3
Black cottonwood	3
Bitter cherry	2
Other species	1

Stand level assessments

Non-aspen competition was present in 91.7% of NE California aspen stands (Table 3). The majority of competition was from conifers with white fir being the primary competing species on most USFS lands and western juniper being the primary competing species on most BLM lands. Hardwood competition was insignificant in the majority (95.6%) of the surveyed stands. However, curl-leaf mountain mahogany was observed to be the primary competitor with aspen in four BLM stands.

Risk ratings assigned to individual stands were subjective and based on the condition of the aspen overstory, levels of regeneration and non-aspen competition. A high risk rating was given to stands that had severe competition, poor aspen overstory and inadequate aspen regeneration.

Table 3. Non-aspen competition (stand level assessment)

Ownership	# of stands	% of stands w/ non-aspen competition	% Competition Type		
			Conifer	Hardwood	Both
All	91	91.7	75.0	6.0	19.0
BLM	14	64.3	44.4	44.4	11.1
Modoc NF	22	95.5	81.0	0.0	19.0
Lassen NF	25	96.0	75.0	4.2	20.8
Plumas NF	17	100.0	82.4	0.0	17.6
Tahoe NF	13	100.0	76.9	0.0	23.1

Moderate risk ratings were assigned if there was non-aspen competition but adequate regeneration and an intact overstory. The majority of the 91 stands were assigned to the moderate (41.8%) and high risk (39.5%) categories suggesting many NE California stands are in a poor condition (Table 4). Many stands that had recent conifer removal treatments still fell into the moderate category due to limited regeneration and/or poor overstory condition. Although the majority of stands received elevated risk ratings, only 29.7% were described as retreating, a condition characterized by limited aspen regeneration. 47.2% were described as stable (300 – 500 aspen sprouts/acre within the stand) and 23.1% were described as expanding (>500 aspen sprouts/acre within and outside of the main stand).

Table 4. Risk rating and stand direction (stand level assessment)

Ownership	# of stands	Risk Rating (% of stands)			Stand Direction (% of stands)		
		High	Moderate	Low	Expanding	Retreating	Stable
All	91	39.5	41.8	18.7	23.1	29.7	47.2
BLM	14	28.6	64.3	7.1	21.4	14.3	64.3
Modoc NF	22	54.6	31.8	13.6	18.2	27.3	54.5
Lassen NF	25	48.0	40.0	12.0	28.0	48.0	24.0
Plumas NF	17	23.5	35.3	41.2	35.3	5.9	58.8
Tahoe NF	13	30.8	46.2	23.0	7.6	46.2	46.2

Animal browsing was detected in 70.3% of surveyed aspen stands (Table 5). Most often, the animal responsible for the observed damage could not be identified because the browsing was too old and clear signs were lacking. However, browsing by cattle was confirmed on all ownerships except for the Alturas Field Office and browsing by deer was confirmed on the Modoc and the Lassen National Forests.

Table 5. Large ungulate browsing (stand level assessment)

Ownership	# of stands	Stands with browsing (%)	Suspected animal (%)		
			Cattle	Deer	Unknown
All	91	70.3	32.8	12.5	54.7
BLM	14	42.9	50.0	0.0	50.0
Modoc NF	22	77.3	35.2	11.8	52.9
Lassen NF	25	64.0	25.0	12.5	62.5
Plumas NF	17	70.6	33.3	0.0	66.7
Tahoe NF	13	100.0	23.1	0.0	76.9

Damage agents were assessed at the stand level to create a general list without assigning damage level or significance. Seventy-eight different insect, disease, animal and abiotic agents were documented for the 91 stands. Table 6 lists the five most commonly encountered agents and the percentage of stands where they were observed. Sooty-bark canker (*Encoelia pruinosa*) was the most common disease agent and bronze poplar borer (*Agrilus liragus*) (Figures 3 & 4) and large aspen tortrix (*Choristoneura conflictana*) (Figure 2) were the most common insect agents.

(A list of all agents recorded at the stand level is found in Appendices B-D)

Figure 2. Large aspen tortrix larva (*Choristoneura conflictana*) (photo: W.Ciesla)

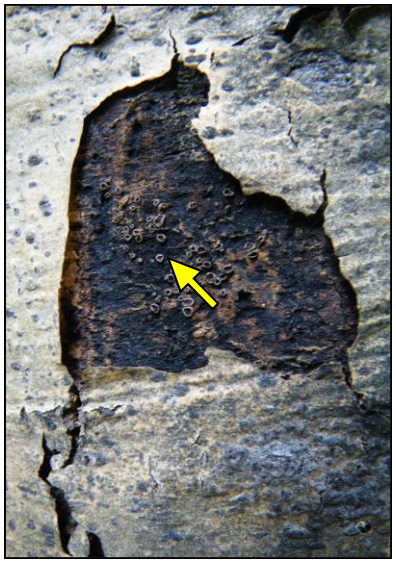

Figure 3. Sooty-bark canker (*Encoelia pruinosa*) with diagnostic cup-shaped fruiting bodies.

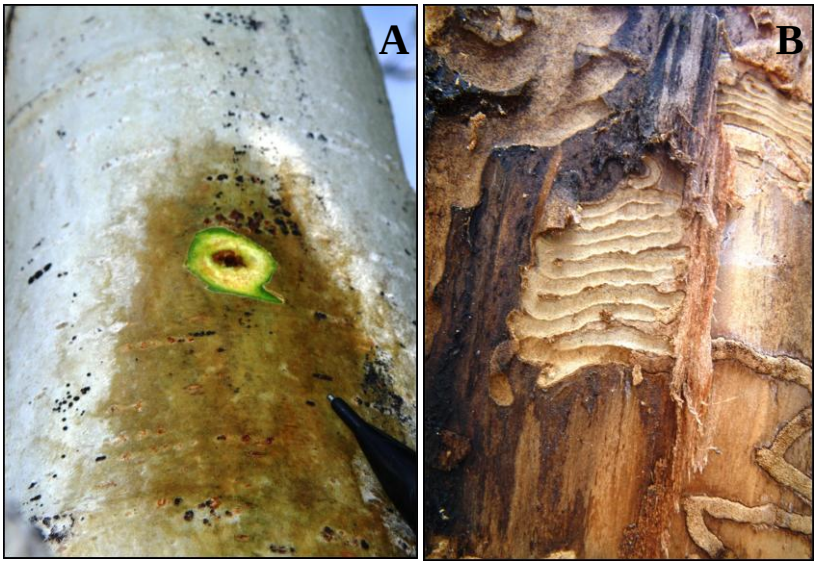

Figure 4. (A) External signs of attack and (B) zigzagging larval feeding gallery of the bronze poplar borer (*Agrilis liragus*).

Table 6. Five most detected damaging agents (stand level assessment)

Ownership	# of stands	% of stands with potentially damaging agent				
		Sapsucker	Sooty-bark canker	Cytospora canker	Bronze poplar borer	Large aspen tortrix
All	91	81.3	76.9	72.5	72.5	72.5
BLM	14	64.3	85.7	85.7	64.3	57.1
Modoc NF	22	81.8	91.0	68.2	68.2	77.3
Lassen NF	25	80.0	64.0	76.0	72.0	72.0
Plumas NF	17	88.2	70.6	58.8	76.5	88.2
Tahoe NF	13	92.3	76.9	76.9	84.6	61.5

Plot level tree data summary

Table 7 summarizes plot results for live and dead aspen, level of dieback and sprout abundance. A total of 4,152 live aspen stems were examined during this survey; 3,137 sprouts, 182 saplings and 833 trees. Tree sized aspen were the focus of plot selection as they tend to contain the

majority of damaging agents within their stems, roots and foliage. Many stands where plots were established contained two cohorts; a decadent overstory and relatively healthy regeneration in the understory in terms of individual stem condition.

Table 7. Summary plot statistics for all NE California plots (n = 91)

Attribute	Mean	StDev	Range
Live aspen ≥ 5.0" dbh (trees)	9.2	5.9	1 – 29
Live aspen 2.0 - 4.9" dbh (saplings)	2.0	3.4	0 – 18
Live aspen < 2.0" dbh (sprouts)	34.5	41.9	0 – 240
Dead aspen ≥ 5.0" dbh	1.0	1.6	0 – 8
Dead aspen 2.0 - 4.9" dbh	0.1	0.3	0 – 2
Dead aspen < 2.0" dbh	2.7	5.3	0 – 26
% dead stems/plot	9.3	11.4	0 – 50.0
% aspen > 2.0" dbh with no dieback	0	0	0
% aspen > 2.0" dbh with light dieback	41.8	29.6	0 – 100
% aspen > 2.0" dbh with moderate dieback	39.0	24.9	0 – 100
% aspen > 2.0" dbh with severe dieback	19.2	22.6	0 – 100
Aspen sprouts/acre*	3450	4190	0 - 24000
% of plots with sprouts	94.5	-	-

* Many sampled stands were < 1 acre.

Dead aspen represented 7.7% of the total number of stems observed among all plots. This mortality included 10.1% of trees, 4.2% of saplings and 7.8% of sprouts. 52.9% of the dead stems were labeled as recent dead (bark intact) and 47.1% were labeled as older dead (bark sloughing). Average per plot mortality of all aspen stems was 9.3%. However, the level of mortality for aspen trees (> 5.0" dbh) was likely much higher at the stand level because plot selection was biased towards pockets of live trees.

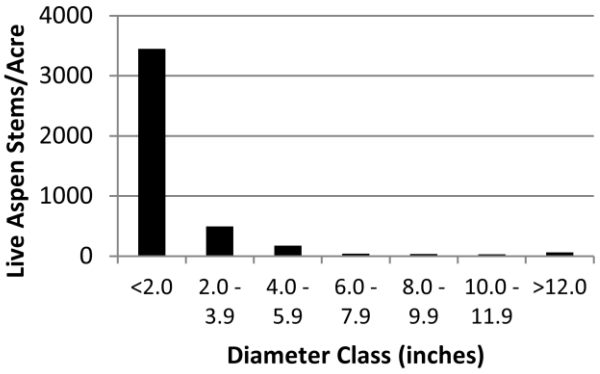

Figure 5. Mean number of stems per acre by 2.0" diameter classes.

The level of crown dieback was recorded for both aspen trees and saplings at each plot. The percentage of trees identified with moderate dieback (33 - 66% of the crown) and severe dieback (> 66% of the crown) averaged 39.0% and 19.2% respectively.

Aspen regeneration was present on 94.5% of the plots at a calculated average of 3,450 sprouts/acre and 500 saplings/acre. Figure 5 illustrates the average number of aspen stems/acre by diameter class for all plots.

Plot level damage agent summary – trees and saplings

Plot level data on primary, secondary and tertiary agents, as determined by the relative level of injury each agent inflicted on individual stems, was collected for all aspen trees and saplings (Tables 8 – 10). Animal damage (sapsucker feeding, *Sphyrapicus* spp.) and mechanical damage (either human caused or of unknown origin) were the most frequently recorded categories causing the highest levels of injury (Figure 6). Six different canker or canker-like diseases,

including black canker (*Ceratocystis fimbriata*), were among the most frequently encountered disease agents (Figure 7). The bronze poplar borer was the most frequently recorded insect agent followed by the large aspen tortrix.

Figure 6. Sapsucker (*Sphyrapicus* spp.) caused stem injury.

Figure 7. Black canker caused by *Ceratocystis fimbriata*.

Several species of woodboring and foliar insects were documented on all plots. All of the woodborers were beetles (Order Coleoptera), found on 92.3% of the plots, with the bronze poplar borer being the most recorded species. Foliage feeding insects were documented on 68.1% of the plots with the large aspen tortrix being the most recorded. This percentage may under represent foliage feeding insects because some plots were sampled early in the growing season before larval feeding began.

Diseases recorded as damaging agents on plots included several canker diseases (recorded on 96.7% of plots), foliar diseases (34.1%), root diseases (3.3%) and stem decays (38.5%). Canker diseases caused the most branch dieback and tree mortality. The two most frequent canker diseases were sooty-bark canker and aspen gall disease (*Diplodia tumefaciens*).

Table 8. Primary damage agents for aspen stems > 2" dbh for all NE California plots (n = 91)

Damage agent	% positive plots	% affected stems on positive plots	% affected stems on all plots
Mechanical injury (unknown origin)	79.1	26.3	23.0
Sapsucker (*Sphyrapicus* spp.)	71.4	30.0	23.9
Canker (not identified)	36.3	10.2	3.0
Sooty-bark canker (*Encoelia pruinosa*)	36.3	13.9	5.9
Bronze poplar borer (*Agrilus liragus*)	36.3	12.8	5.0
Aspen gall disease (*Diplodia tumefaciens*)	33.0	14.9	6.6
Black canker (*Ceratocystis fimbriata*)	22.0	16.7	3.6
Mechanical injury (human caused)	18.7	12.7	3.5
Hypoxylon canker (*Hypoxylon mammatum*)	16.5	20.7	4.5
Rough bark disease (*Rhytidiella baranyayi*)	8.8	14.9	2.1

Table 9. Secondary damage agents for aspen stems > 2" dbh for all NE California plots (n = 91)

Damage agent	% positive plots	% affected stems on positive plots	% affected stems on all plots
Mechanical injury (unknown origin)	68.1	19.8	15.8
Sapsucker (*Sphyrapicus* spp.)	64.8	17.5	12.6
Canker (not identified)	44.0	12.1	5.9
Aspen gall disease (*Diplodia tumefaciens*)	42.9	15.1	7.4
Bronze poplar borer (*Agrilus liragus*)	40.7	12.2	5.9
Sooty-bark canker (*Encoelia pruinosa*)	36.3	11.7	4.6
Mechanical injury (human caused)	24.2	15.4	4.4
Woodborer (not identified)	20.9	15.2	3.3
Large aspen tortrix (*Choristoneura conflictana*)	19.8	10.4	2.8
Poplar branch borer (*Oberea schaumii*)	16.5	14.4	3.1

Table 10. Tertiary damage agents for aspen stems > 2" dbh for all NE California plots (n = 91)

Damage agent	% positive plots	% affected stems on positive plots	% affected stems on all plots
Mechanical injury (unknown origin)	63.7	13.1	10.0
Canker (not identified)	50.5	10.8	6.7
Sapsucker (*Sphyrapicus* spp.)	49.5	12.9	7.6
Bronze poplar borer (*Agrilus liragus*)	48.4	13.5	7.1
Large aspen tortrix (*Choristoneura conflictana*)	42.9	15.2	8.3
Mechanical injury (human caused)	40.7	10.8	5.4
Woodborer (not identified)	30.8	10.5	3.5
Sooty-bark canker (*Encoelia pruinosa*)	29.7	9.8	3.4
White trunk rot (*Phellinus tremulae*)	25.3	14.1	3.8
Leafhoppers (various species)	20.9	9.8	3.0

Animal damage caused by sapsucker feeding and/or mechanical damage (either human caused or of unknown origin) were present on all plots.

Plot level damage agent summary – regeneration

Browsing by both wild and domestic ungulates was the most frequently recorded primary damaging agent on aspen sprouts (47.3% of plots and 36.2% of all sprouts examined) (Figure 8). Shoot and leaf diseases such as shoot blight, or "Sheppard's Crook" (*Venturia tremulae*), Marssonina leaf spot (*Marssonina populi*) and ink spot (*Ciborinia whetzelli*) were the most frequently encountered primary disease agents. Secondary/tertiary agents included foliar insects such as various species of caterpillars and leafhoppers (Figure 9).

(Summary data for each National Forest and combined for Bureau of Land Management field offices are found in Appendix E)

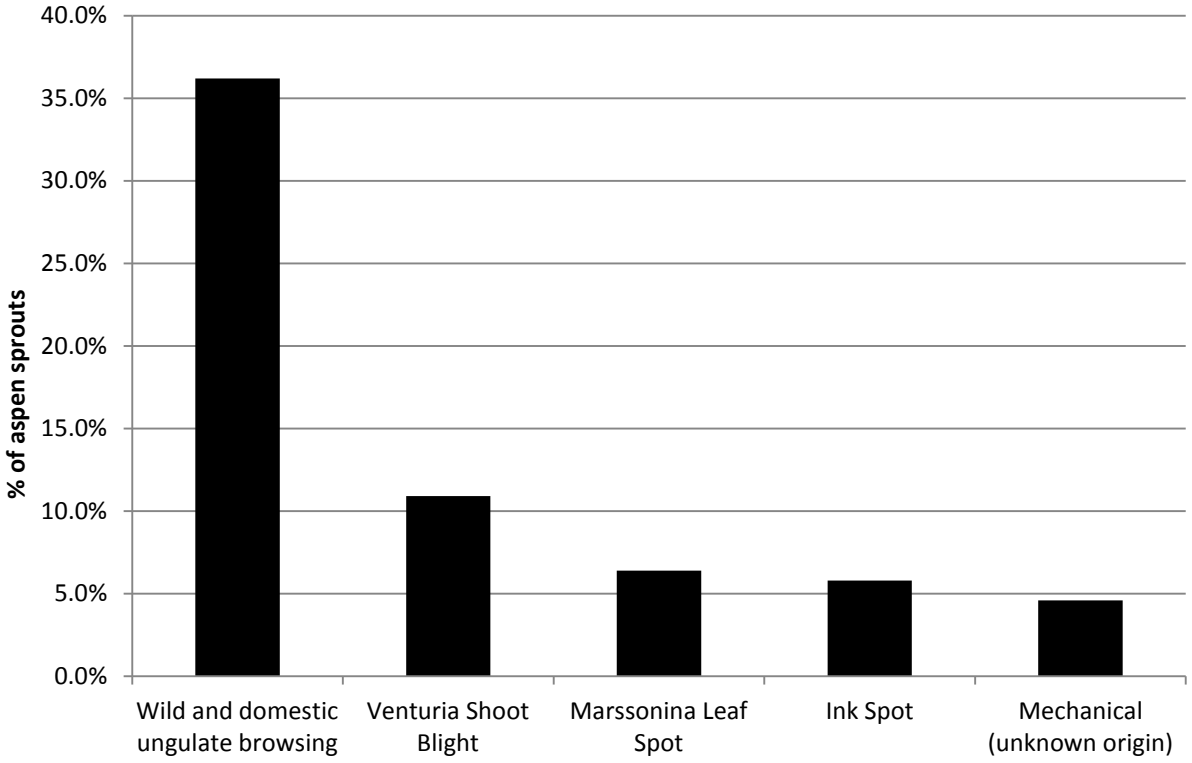

Figure 8. Most common primary damage agents on aspen sprouts for all NE California plots (n = 91)

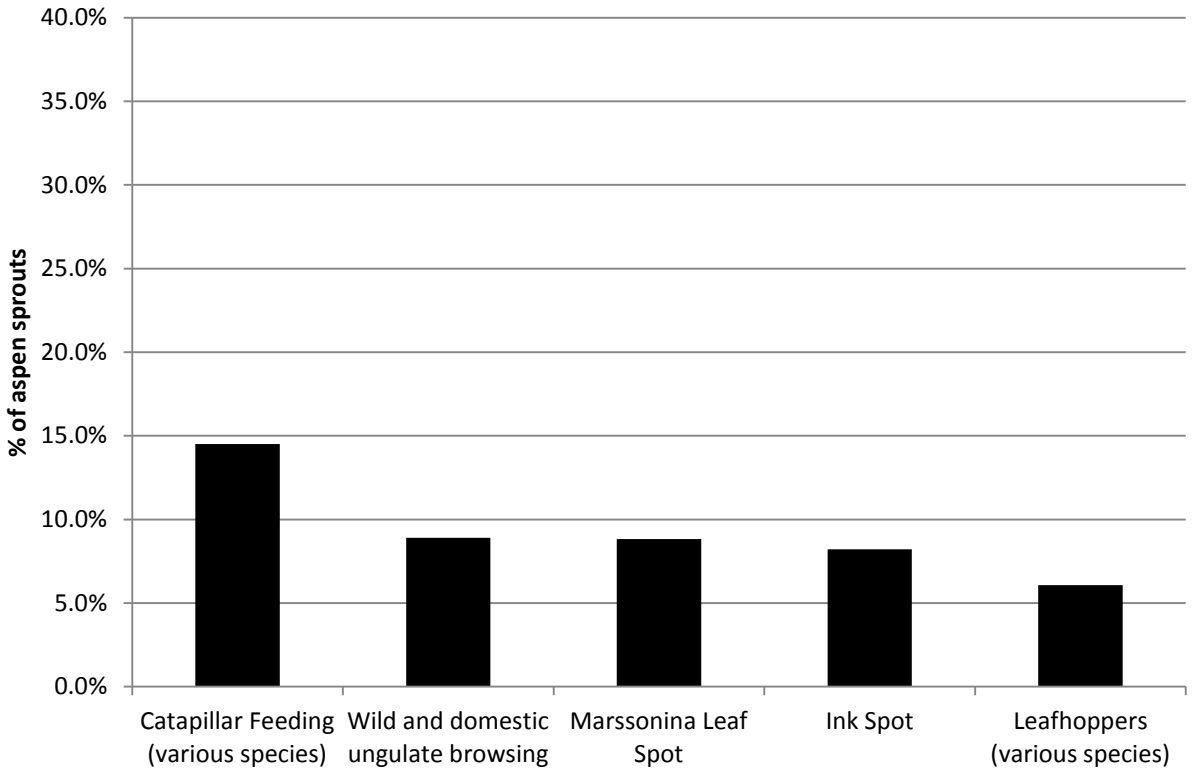

Figure 9. Most common secondary/tertiary damage agents on aspen sprouts for all NE California plots (n = 91)

Potential of most frequently recorded damaging agents to cause mortality

For each agent, the severity of damage was also recorded. The severity rating was based on the percent of the bole circumference affected with a few exceptions (such as substituting percent leaf area for foliar agents) (Table 11).

Table 11. List of frequently recorded agents with moderate to high severity ratings

Agents with highest number of moderate to high severity ratings on trees and saplings	Potential to cause mortality
Sapsucker (*Sphyrapicus* spp.)	Low
Mechanical injury (human and unknown origin)	Low
Sooty-bark canker (*Encoelia pruinosa*)	High
Aspen gall disease (*Diplodia tumefaciens*)	Low
Bronze poplar borer (*Agrilus liragus*)	Moderate
Agents with highest number of moderate to high severity ratings on sprouts	**Potential to cause mortality**
Animal browsing (wild and domestic ungulates)	High
Mechanical injury (human and unknown origin)	Moderate
Shoot blight (*Venturia tremulae*)	Low
Animal trampling (large ungulates)	Moderate
Marssonina leaf spot (*Marssonina populi*)	Low

Some damaging agents of trees and saplings that cause mechanical bole injuries, such as sapsuckers and other biotic and abiotic agents may have had the level of severity recorded as high but the direct threat to tree survival is low. The primary concern for these types of injuries is their role in providing entry courts for diseases. Other damaging agents with high severity ratings are significant threats to tree survival. Canker diseases represent the greatest threat to aspen survival as the presence of some, such as sooty-bark canker, indicate imminent tree mortality. White trunk rot (*Phellinus tremulae*) did not receive severity ratings because its presence typically threatens tree survival only after many years when decayed trees fail (Figure 10). The bronze poplar borer mainly plays a secondary role by attacking severely diseased and dying trees. However, under drought conditions, this beetle can successfully attack and kill relatively healthy trees.

Figure 10. Conk of *Phellinus tremulae*, or white trunk rot.

Aspen sprouts also had several agents recorded with a high severity levels but low potential to cause mortality. Foliar diseases such as shoot and leaf blights may cause significant defoliation but seldom lead to sprout mortality. Mechanical injury, including trampling by livestock, can lead to mortality if injuries are repeated and/or

severe. Animal browsing has a high potential to cause mortality if sprouts are repeatedly consumed.

Treated vs. untreated plots (conifer removal)

Conifer removal treatments were divided into two categories; western juniper removal on BLM lands and mixed conifer (ponderosa, Jeffrey and lodgepole pine and white fir) removal on BLM and USFS lands. Few differences in aspen stand structure were observed for plots that had recent conifer removal treatments vs. untreated plots. However, regeneration was slightly higher in treated stands. Total number of damaging agents (from stand level list), percent dieback and mortality were also similar. Additional monitoring and analysis of treated and untreated plots is planned to detect changes over time.

Treated vs. untreated plots (burning)

Burned plots had fewer trees and saplings but more seedlings compared to unburned plots indicating that fire removed some overstory trees but increased sprouting (5900 sprouts/burned acre to 2967 sprouts/unburned acre). Burned plots also had fewer damaging agents detected than unburned plots. This is likely due to fewer large trees and more undamaged regeneration. The mature stems that did occur in burned plots had more crown dieback, mostly due to fire injuries. Future Forest Health Protection reports will document any long-term changes associated with burned vs. unburned plots.

Plot level comparisons of important aspen health indicators between management areas

Table 12 displays four plot level aspen stand health attributes (conifer invasion, overstory dieback, regeneration and overall stand mortality) and Table 13 displays three important damaging agents (animal browsing, sooty-bark canker and bronze poplar borer) among the four NE California national forests and combined BLM resource areas.

Table 12. Major aspen stand health attributes by ownership (plot level)

Ownership	# of plots	% conifer in overstory / understory	mean % aspen w/moderate and severe dieback	mean % aspen sprouts / plot	mean % aspen mortality >5" dbh
BLM	14	3.8 / 34.5	73.1	14.9	16.1
Modoc NF	22	20.7 / 40.9	67.2	21.7	10.6
Lassen NF	25	30.2 / 35.2	54.8	37.6	8.0
Plumas NF	17	34.0 / 20.7	42.8	35.4	9.0
Tahoe NF	13	42.5 / 30.2	53.8	59.4	9.2

Table 13. Major damaging agents by ownership (plot level)

Ownership	# of plots	% sprouts w/browsing	% of plots w/sooty-bark canker primary / secondary	% of plots w/bronze poplar borer primary / secondary
BLM	14	29.9	71.4 / 57.1	35.7 / 42.9
Modoc NF	22	45.6	36.4 / 36.4	36.4 / 36.4
Lassen NF	25	37.3	28.0 / 24.0	28.0 / 32.0
Plumas NF	17	29.4	29.4 / 29.4	41.2 / 41.2
Tahoe NF	13	37.5	23.1 / 46.2	46.2 / 61.5

Aspen plots on combined BLM lands had the highest level of aspen tree mortality (>5" dbh), the highest level of moderate to severe dieback and the lowest number of sprouts. BLM plots also had a high incidence of sooty-bark canker. Plots on the Modoc National Forest (MDF) had a higher level of dieback and a lower number of sprouts relative to the other national forests. The MDF also had the highest percentage of browsing on sprouts followed by the Lassen (LNF) and the Plumas National Forests (PNF). The Tahoe National Forest (TNF) had the highest average percentage of aspen sprouts/plot, the highest percentage of conifers in the overstory, and had the highest incidence of bronze poplar borer. Overstory conifers were scarce on BLM plots mostly due to recent removal treatments. The percentage of understory conifers was lowest on the PNF.

DISCUSSION

This survey was the first attempt to collect information on damaging agents of aspen in NE California. Since insects and diseases were the primary focus, selected aspen stands were biased towards large stands that contained more > 5.0" dbh trees suitable for evaluation. These aspen stands on average are likely in a healthier condition than many smaller NE California stands. The fact that 87% of the plots showed aspen as the dominant species further suggests that these stands may not be representative of the small conifer-dominated stands that are common in NE California. Additionally, plot selection within stands was biased to capture the large dbh live trees while ignoring more decadent portions of a particular stand. Per acre regeneration figures are also slightly misleading because many of the surveyed stands were less than one acre in size and/or regeneration distribution within stands was highly variable. The more subjective stand level assessments attempted to compensate for these plot level biases.

The stand level assessment for NE California found that 41.8% of stands were at a moderate risk and 39.5% were at a high risk of disappearing from the landscape; based on having one or more risk factors. Bartos and Campbell (1998) describe certain high risk factors for aspen stands. Two of these factors are having fewer than 500 regeneration stems per acre (5 - 15 feet tall) and having dominant aspen trees being older than 100 years of age. This survey did not measure stem height or determine tree age so there is no way to directly compare data to these risk factors. However, many aspen stands in NE California have two distinct layers; a decadent overstory (60% of trees dead or with moderate to severe dieback) and an understory with adequate sprouts (3450 sprouts/acre average). Based on tree size and lack of known stand replacing disturbance, many of the overstory trees could be 100+ years in age and most regeneration was < 5 feet tall. Thus the majority of NE California aspen stands are at risk according to two different risk assessments. Barring any unforeseen mortality events, regeneration in most of the surveyed stands should at least meet the 500, 5 – 15 foot stem/acre criteria in a few years and eventually replace the declining overstory.

The level of mortality and dieback found in NE California suggests that large mature aspen trees are disappearing from many aspen stands as they succumb to various insects, diseases and abiotic agents including periodic drought. However, the presence of healthy regeneration in the majority of stands indicates that these aspen stands have a good chance of surviving in the near future.

The bronze poplar borer was the most documented woodborer in NE California. This beetle is considered one of the most aggressive species of woodborers that attack aspen. The bronze poplar borer tends to attack older trees and trees that are weakened by mechanical and animal

damage, drought or disease. Their attacks can also provide entry courts for diseases such as Cytospora (*Cytospora chrysosperma*) and Hypoxylon cankers (*Hypoxylon mammatum*). In aspen stands with decadent overstory trees, the bronze poplar borer was commonly associated with crown dieback and mortality.

The large aspen tortrix was the most documented foliage feeder. This moth species is widespread throughout the western range of aspen occasionally causing complete defoliation during outbreaks. However, the large aspen tortrix has many insect parasites that typically keep the population in check. When outbreaks do develop, trees may be completely defoliated for one or two years, reducing growth. Once larvae deplete all aspen foliage, they starve and the population collapses. Streamside shading and wildlife cover may be impacted for the duration of an epidemic (Schmidt 2000). None of the observations of large aspen tortrix in NE California were associated with an outbreak.

Sooty-bark canker was the most frequently recorded disease in NE California. Sooty-bark canker is considered the most deadly canker pathogen of aspen in the West (Hinds 1985), typically killing trees in 3 to 10 years. Large cankers produce a characteristic black striped "barber pole" pattern on the trunk. Snake canker (*Cryptosphaeria populina*) is also considered a deadly pathogen of aspen. Although found on both USFS and BLM lands, snake canker only made the top ten list of primary and secondary agents on the MDF.

Aspen gall disease (*Diplodia tumefaciens*), sometimes referred to as corky bark disease, was the second most frequently recorded disease in NE California. Aspen gall disease causes small spherical galls at the base of twigs or larger oval shaped rough galls on the stem. Bark wounds can provide entry courts for the disease and subsequent gall formation, however, this disease has very little effect on tree health.

Mechanical injury to stems from sapsucker feeding was the most common recorded damage in NE California. Sapsuckers drill horizontal rows of holes to obtain sap and eat insects that are attracted to the sap. This type of injury creates entry courts for diseases and can sometimes girdle trees resulting in top kill or stem breakage.

Browsing of aspen regeneration by wild and domestic ungulates was high in NE California, recorded as the primary damaging agent on 43.2% of sprouts on 47.3% of plots. At the stand level, 70.3% had evidence of browsing. While no stand was found to be completely denuded of aspen foliage, the repeated pressure of browsing may be slowing the growth of affected stems and delaying their recruitment into the overstory (Jones et al 2009). As regeneration matures and reaches > 5 feet in height, the impacts of any animal browsing will be greatly reduced as terminal leaders and upper foliage will be out of reach (Sheppard et al 2006).

Venturia shoot blight and Marssonina leaf spot were the two most frequently recorded diseases on aspen sprouts. The magnitude of these diseases can be exacerbated by warm and wet spring weather, which was the condition that occurred the year of the survey. Several stands that had high levels of Marssonina leaf spot were revisited later in the summer to assess any impacts to growth and mortality. Nearly all infected trees had regrown foliage and were in a relatively healthy condition.

A few trends were revealed in the comparison of aspen stand health attributes to important damaging agents among the MDF, LNF, PNF, TNF and combined BLM. The level of overstory mortality is slightly higher and the number of sprouts is lower in the more northern and eastern stands located on the MDF and BLM. The combination of these two attributes put stands in these areas at a higher risk of being lost from the landscape. However, the level of overstory conifer competition in the MDF and BLM stands is lower than more southern and western areas. As overstory aspen disappear from the landscape in these areas it is crucial to protect the limited regeneration from excessive browsing until stems reach at least 5' in height. The percentage of browsed aspen sprouts was highest on the MDF. This browsing combined with a high percentage of understory conifers further increases the risk of losing many MDF stands. Additionally, the presence of sooty-bark canker on the BLM plots was much higher compared to the rest of the survey area. Since sooty-bark canker typically leads to stem death, a high level of overstory mortality is expected in the near future in these stands.

Overstory conifer encroachment levels were higher on the southern and western aspen stands occurring on the LNF, PNF and TNF. Plots on these three national forests averaged > 25% conifers in the overstory species composition and both the LNF and TNF averaged > 25% conifers in the understory species composition. Having > 25% conifer in both the overstory and understory is one of the risk factors describe by Bartos and Campbell (1998).

Aspen stands that received conifer removal treatments were compared to control stands located in the same general area. Aspen stand structure and the level of agents were similar between treated and untreated stands. However, there was a higher number of sprouts/acre in the conifer removal stands. This was expected with the removal of the conifer canopy and corresponding increase in sunlight to the forest floor. These conifer removal treatments have mostly occurred in the last 10 years and the differences in aspen stand structure between treated and untreated stands are expected to increase over time.

Differences in methods among all of the western regional surveys made direct comparisons of agents difficult. Therefore, only a few specific disease agents and broad categories of insect agents could be compared. However, the majority of insect and disease agents that are typically associated with aspen damage were found throughout the west, including NE California. Two of the most common damage agents for this survey were sooty-bark canker and bronze poplar borer. This is similar to results that Guyon and Hoffman (2011) and Steed and Kearns (2010) reported for their respective aspen surveys in Idaho, Nevada and Utah and in Montana and northern Idaho. Notable differences in NE California compared to these other surveys included lower incidences of aspen bark beetles and Cytospora canker.

Suspected damage from bark beetles was observed in 12% of the plots in NE California. Recently, aspen bark beetles have been found in abundance in southwest Colorado. There they were associated with SAD stands but were not responsible for mortality. Very little is known about bark and ambrosia beetle species of aspen in California. It is presumed that they are rare and seldom cause mortality. Aspen bark beetles were also detected at low levels in Idaho, Nevada and Utah but were described as becoming more significant damage agents in ongoing aspen dieback (Guyon and Hoffman 2011).

The low incidence of Cytospora canker in NE California may be related to the bias in plot selection towards areas with live trees. Large visible Cytospora cankers tend to be more common

on stressed, dying or dead trees (Guyon et al 1996) that may have been underrepresented in the plots. When assessed at the stand level, Cytospora canker was found in 72.5% of surveyed stands. Underestimates of Cytospora may also be attributed to the inability to identify old cankers, listing them simply as bark wounds instead.

Animal damage to trees and saplings was very high in NE California aspen stands. The majority of this damage was attributed to sapsucker feeding. The other region with a high incidence of animal damage to trees was nID/MT. The nID/MT survey listed sapsuckers as a high primary agent in eastern Montana and a high secondary/tertiary agent in western Montana and northern Idaho (Steed and Kearns 2010).

The overall percentage of aspen tree mortality was 10.1% in NE California. Whether this level of mortality is higher or lower than normal is not clear as there is little published data describing aspen mortality rates. Guyon and Hoffman (2011) reported a 30% mortality rate and Steed and Kearns (2010) reported an overall approximate mortality rate of 10%. The Guyon and Hoffman (2010) survey plots were located within previously mapped aspen dieback polygons, which may explain the higher rate.

The temporal pattern of aspen mortality in NE California was much different from the other western regions. 47.1% of dead aspen trees were recorded as older dead as compared to 0 to 33% for all other western regional surveys. This suggests that NE California experienced a distinct mortality pulse earlier than the rest of the west or that mortality has been occurring steadily over a longer period of time.

Sheppard (2008) describes sudden aspen decline (SAD) as mortality of mature trees within 1 – 2 years combined with a lack of new regeneration. As previously mentioned, there appears to be a rather rapid die off of mature aspen stems throughout NE California but it is occurring over a period longer than 1 – 2 years. There also does not appear to be any excessive mortality of sprouts because most stands with high levels of overstory mortality have a large number of healthy sprouts in the understory. Based on these observations, it does not appear that SAD is occurring in NE California.

CONCLUSION

This survey was the first effort to document insect and disease agents in California aspen stands. Many common insect and disease agents of aspen that are found throughout the west were also found in NE California. Despite the presence of these common insect and disease agents, they are impacting aspen health far less than other biotic factors such as animal browsing and conifer encroachment and abiotic factors such as drought. While it is important for land managers to be aware of the potential for damage by insect and disease agents, the impacts of browsing and conifer encroachment are a more imminent concern. Removing conifers and/or burning aspen stands can effectively remove competition and encourage regeneration. However, treating stands without protecting new sprouts from browsing can result in losing aspen from the landscape (Sheppard et al 2006). Once treated by removing conifers and protecting regeneration, vigorous stands will be more resilient to the impacts of any native insect or disease agent.

A decline, characterized by the dieback and mortality of large diameter aspen stems, in many NE California aspen stands is occurring. However, most of the stands where this is occurring appear

to have adequate regeneration. This type of decline does not fit the definition of SAD nor does it necessarily indicate that these stands are at a high risk of disappearing from the landscape in the near future.

NE California aspen plots will be revisited at 5 or 10 year intervals to document short and long-term changes in stand structure and impacts of damaging agents (biotic and abiotic). Future analysis will include plots with conifer removal/burning vs. control to more fully describe treatment effects.

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Appendix A. Data definitions

HEADER DATA	
Plot #	3 to 5 letter land manager code (e.g. EBLM = Eagle Lake Bureau of Land Management) + 2-number identifier
Date	mm/dd/yyyy
Crew	initials of all crew members
State	2 letter state code (MT=Montana, ID=Idaho)
County	county
Ownership	land manager (FS=Forest Service,BLM=Bureau of Land Management)
NF/RD/FO	name of National Forest, Ranger District, Field Office, etc.
T/R/Sec (optional)	Township / Range / Section
maps (optional)	name of best map for locating site
GPS parking	NAD83, UTM coordinate of good parking spot
GPS other pts (optional)	NAD83, UTM coordinate of other important points, especially for locating or accessing plot
GPS plot center	NAD83, UTM coordinate of plot center (stake)
GPS center elevation	plot center elevation in feet above sea level per GPS coordinate
Primary tree sp	4-letter genus-species code of dominant tree species (over and understory combined)
Secondary tree sp	4-letter genus-species code of secondary tree species (over and understory combined)
Slope	slope in degrees as average of values looking upslope and down slope from center
Aspect	aspect in degrees
Slope position	RIDGE TOP or SLOPE or VALLEY BOTTOM
Riparian adjacency and type	none, creek, spring, meadow, etc
Stand direction	RETREATING (<300 aspen sprouts/acre or loss of mature stems with none aspen replacements), STABLE (300 – 500 aspen sprouts/acre within stand), EXPANDING (>500 aspen sprouts/acre within and outside of the stand)
Non-aspen competition	NO (no conifers in dominant or co-dominant and little to no conifer regeneration), YES (conifers in stand but usually <25% in co-dominant or dominant), SEVERE (if conifer competition affecting stand condition; usually >25% of dominant or co-dominant), CONIFER or DECIDUOUS
Successional status	STABLE (aspen regenerating at >500 sprouts/acre; expected to remain as an aspen-dominated stands for many years to come), SUCCESSIONAL (barring disturbance stand likely to continue succession toward being conifer-dominated; conifer competition would likely have to be 'yes')
Vegetation Type succeeding towards	4-letter genus-species codes of the principle tree species likely to dominate site barring disturbances (often includes any non-aspen species listed in primary or secondary tree species)
Animal browsing; responsible animal	browsing present, cattle, elk, deer, other
Risk	LOW (sufficient regeneration, > 300 aspen sprouts/acre, no non-aspen competition, intact aspen overstory), MODERATE (>300 sprouts/acre, intact aspen overstory, 1 – 25% non-aspen competition), HIGH (<300 aspen sprouts/acre, decadent overstory, >25% non-aspen competition)

Photographs taken	all plots have 5 photos minimum (toward center showing stake, from stake looking N, E, S, and W); also agent photos or others of interest
Stand level agent list	survey entire stand if small and a majority of stand if large and record all agents observed regardless of severity level
TREE and SAPLING DATA	
Tree species	4-letter genus-species code (e.g. POTR for *Populus tremuloides* or PSME for *Pseudotsuga menziesii*)
ID	tag number for TREES (tags placed at DBH and facing toward center starting with trees at N and working clockwise) : subplot number (angle from center: 0, 120, 240) + 2-number count (e.g. 01, 02) for SAPLINGS
DBH	diameter at breast height (DBH) (4.5 feet) recorded in inches
Dieback	determined as the percentage of crown dieback; categorized into one of four classes: 0=no dieback (rare); 1=<33% of crown lost, 2=33-66% of crown lost, 3=>66% of crown lost
Tree Condition	0=live tree (at least one green leaf), 1=recently dead (90% of bark still attached), 2=older dead (bark detaching or partially detached, still has at least 50% of bark attached)
Crown Class	dominant, co-dominant, intermediate, suppressed, open grown, or spike topped (broken or dead top)
Damage 1	aspen only - identification number of damage agent that is having or has had the greatest impact on future survival
Severity 1	rating of 1 to 3 with 1=light damage of cambium over <33% of circumference, 2=moderate damage of cambium over 33-66% of circumference, 3=heavy damage of cambium of >66% of circumference, often resulting in death)
Damage 2	identification number of damage agent that is having or has had the second greatest impact on future survival
Severity 2	(as with Severity 1)
Damage 3	identification number of damage agent that is having or has had the third greatest impact on future survival
Severity 3	(as with Severity 1)
Damage/severity definition exceptions	sapsucker – one line of holes may cover 100% of circumference but have light severity. 2 – 10 lines covering 100% is moderate and >10 lines covering 100% of circumference is high snake canker – moderate if narrow in width but very long (1.5 -3 ft in length), severe if >3 ft in length bronze poplar borer – 1 to 4 attacks = light, 5 to 11 attacks = moderate, >12 attacks = high foliar agents – the amount of leaf area affected, light is 1 – 33%, moderate is >33-66%, high is >66% no severity ratings assigned to dead trees no severity ratings assigned to trees with trunk rot, broken top, nest cavity, and root and butt rots
REGENERATION DATA	
Tree species	4-letter genus-species code (e.g. POTR5 for *Populus tremuloides* or PSME for *Pseudotsuga menziesii*)
Degree	subplot angle from center (0, 120, or 240)
Seedling Count	number of aspen seedlings, live and dead, <2-inches diameter with no minimum height requirement
Damage 1	aspen only - identification number of damage agent that has greatest impact on the greatest number of stems

Dam1%	percentage of seedlings with this damage agent present
Severity 1	average severity rating for seedlings with this first damage agent [=(#stems with severity1 x 1) + (# stems with severity2 x 2) + (# stems with severity3 x 3) / # stems with agent present]
Damage 2	identification number of damage agent with second greatest impact on greatest number of stems
Dam2%	(as with Damage1%)
Severity 2	(as with Severity 1)
Damage 3	identification number of damage agent with third greatest impact on greatest number of stems
Dam3%	(as with Damage1%)
Severity 3	(as with Severity 1)
Saplings	aspen saplings (2 – 4.9" dbh) are counted within subplots but are not tagged. Record species, crown class, dbh, dieback, tree condition, damage agents with severity ratings non-aspen saplings are counted with species, dbh, crown class and tree condition recorded

Appendix B. List of all agents detected at the stand level

Common name	Scientific name	% of stands recorded
Sapsucker	*Sphyrapicus* spp.	81.3
Sooty-bark canker	*Encoelia pruinosa*	76.9
Cytospora canker	*Cytospora chrysosperma*	72.5
Bronze poplar borer	*Agrilus liragus*	72.5
Large aspen tortrix	*Choristoneura conflictana*	72.5
Leafhoppers	not identified	70.3
Ink spot	*Ciborinia whetzelii*	69.2
Marssonina leaf spot	*Marssonina populi*	64.8
Mechanical (not human or animal related)		64.8
Aspen gall disease	*Diplodia tumefaciens*	62.6
Venturia shoot blight "Sheppard's Crook"	*Venturia tremulae*	59.3
Aspen leafroller	*Pseudexentera oregonana*	59.3
White trunk rot	*Phellinus tremulae*	56.0
Skeletonizer	not identified	54.9
Caterpillar feeding	not identified	50.5
Wildlife cavity		48.4
Aspen two leaf tier	*Enargia decolor*	44.0
Flatheaded borer	not identified	42.9
Frost		42.9
Animal browsing		42.9
Aspen wart disease	*Curcubitaria staphula*	42.9
Canker	not identified	41.8
Woodborer	not identified	41.8
Human mechanical		40.7
Star gallery insect	not identified (bark beetle?)	40.7
Black canker	*Ceratocystis fimbriata*	39.6
Roundheaded borer	not identified	39.6
Eriophyid gall mite	Acari: Eriophyidae	39.6
Animal clawing		37.4
Ambrosia beetle	not identified	34.1
Aspen leaf tier	*Sciaphila duplex*	33.0
Bacterial wetwood	not identified	30.8
Poplar branch borer	*Oberea schaumii*	28.6
Animal rubbing		28.6
Poplar aphid	not identified	27.5
Hypoxylon canker	*Hypoxylon mammatum*	26.4
Poplar borer	*Saperda calcarata*	20.9
Animal trampling		18.7
Snake canker	*Cryptosphaeria populina*	15.4
Poplar-gall Saperda	*Saperda inornata & S. populnea*	14.3
Aspen leaf miner	*Phyllocnistis populiella*	14.3
Broken top		13.2
Aspen rough bark	*Rhytidiella baranyayi*	12.1
Cynipid galls	not identified	11.0
Fire		9.9
Water/flood		9.9
Forest tent caterpillar	*Malacosoma disstria*	8.8

Common name	Scientific name	% of stands recorded
Foliar insect	not identified	6.6
Oystershell scale	*Lepidosaphes ulmi*	6.6
Foliar fungus	not identified	5.5
Cottonwood leaf-curl mite	*Aculus lobulifera*	5.5
Twig gall fly	*Hexomyza schineri*	5.5
Lightning		4.4
Suppression		3.3
Root and butt rot	not identified	2.2
White mottled rot	*Ganoderma applanatum*	2.2
Inky cap	*Coprinus atramentarius*	2.2
Beaver		2.2
Animal debarking		2.2
UNKNOWN		2.2
Spider mite	not identified	2.2
Carpenter ants	*Camponotus* spp.	2.2
Poplar vagabond gall aphid	*Mordwilkoja vagabunda*	2.2
Armillaria	*Armillaria* spp.	1.1
Coal fungus	*Daldinia concentrica*	1.1
Aspen rood girdler	not identified	1.1
Aspen leaf beetle	*Chrysomela crotchi*	1.1
Aspen blotchminer	*Phyllonorycter tremuloidiella*	1.1
Other animal		1.1
Sunscald		1.1
Bracket fungi	*Fomitosis* spp.	1.1
Eastern poplar borer (?)	not identified	1.1
Midge bud gall	*Aceria parapopuli*	1.1
Aspen leaf gall midge	*Prodiplosis morrisi*	1.1

Appendix C. List of insect agents detected at the stand level

Common name	Scientific name	Common name	Scientific name
Ambrosia beetle	not identified	Foliar insect	not identified
Aspen blotchminer	*Phyllonorycter tremuloidiella*	Forest tent caterpillar	*Malacosoma disstria*
Aspen leafroller	*Pseudexentera oregonana*	Large aspen tortrix	*Choristoneura conflictana*
Aspen leaf beetle	*Chrysomela crotchi*	Leafhoppers	not identified
Aspen leaf gall midge	*Prodiplosis morrisi*	Midge bud gall	*Aceria parapopuli*
Aspen leaf miner	*Phyllocnistis populiella*	Oystershell scale	*Lepidosaphes ulmi*
Aspen leaf tier	*Sciaphila duplex*	Poplar aphid	not identified
Aspen rood girdler	not identified	Poplar borer	*Saperda calcarata*
Aspen two leaf tier	*Enargia decolor*	Poplar branch borer	*Oberea schaumii*
Bronze poplar borer	*Agrilus liragus*	Poplar gall Saperda	*Saperda inornata & S. populnea*
Carpenter ants	*Camponotus* spp.	Poplar vagabond gall aphid	*Mordwilkoja vagabunda*
Caterpillar feeding	not identified	Roundheaded borer	not identified
Cottonwood leaf-curl mite	*Aculus lobulifera*	Skeletonizer	not identified
Cynipid galls	not identified	Spider mite	not identified
Eastern poplar borer (?)	not identified	Star gallery insect	not identified (bark beetle?)
Eriophyid gall mite	Acari: Eriophyidae	Twig gall fly	*Hexomyza schineri*
Flatheaded borer	not identified	Woodborer	not identified

Appendix D. List of disease agents detected at the stand level

Common name	Scientific name	Common name	Scientific name
Armillaria	*Armillaria* spp.	Hypoxylon canker	*Hypoxylon mammatum*
Aspen gall disease	*Diplodia tumefaciens*	Ink spot	*Ciborinia whetzelii*
Aspen rough bark	*Rhytidiella baranyayi*	Inky cap	*Coprinus atramentarius*
Aspen wart disease	*Curcubitaria staphula*	Marssonina leaf spot	*Marssonina populi*
Bacterial wetwood	not identified	Root and butt rot	not identified
Black canker	*Ceratocystis fimbriata*	Snake canker	*Cryptosphaeria populina*
Bracket fungi	*Fomitosis* spp.	Sooty-bark canker	*Encoelia pruinosa*
Canker	not identified	Venturia shoot blight	*Venturia tremulae*
Coal fungus	*Daldinia concentrica*	White mottled rot	*Ganoderma applanatum*
Cytospora canker	*Cytospora chrysosperma*	White trunk rot	*Phellinus tremulae*
Foliar fungus	not identified		

Appendix E. Plot summaries by Field Office/National Forest

Bureau of Land Management (BLM)

BLM plot summary: Aspen density, size class, mortality and percent crown dieback (n=14)

Alturas, Eagle Lake and Surprise Field Offices			
	Mean	StDev	Range
Elevation (ft)	6430	432	5551 - 7403
Live aspen ≥ 5.0" dbh (trees)	7.3	3.8	1 - 13
Live aspen 2.0 - 4.9" dbh (saplings)	1.2	2.1	0 - 7
Live aspen < 2.0" dbh (sprouts)	14.9	11.8	1 - 38
Dead aspen ≥ 5.0" dbh	1.4	1.7	0 - 5
Dead aspen 2.0 - 4.9" dbh	0	0	0
Dead aspen < 2.0" dbh	1.2	2.6	0 - 9
% dead stems/plot	9.0	9.4	0 - 29
% aspen > 2.0" dbh with no dieback	0	0	0
% aspen > 2.0" dbh with light dieback	26.9	26.4	0 - 75
% aspen > 2.0" dbh with moderate dieback	41.9	31.5	0 - 92
% aspen > 2.0" dbh with severe dieback	31.2	26.5	0 - 100
Sprouts/acre	1493	1176	100 - 3800
% of plots with sprouts	100.0		

BLM plot summary: Frequency of primary damage agents for aspen stems > 2" dbh (n=14)

Alturas, Eagle Lake and Surprise Field Offices			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Mechanical injury (unknown origin)	78.6	26.0	21.7
Sooty-bark canker (*Encoelia pruinosa*)	71.4	15.0	11.6
Sapsucker (*Sphyrapicus* spp.)	64.3	23.3	17.4
Canker (not identified)	42.9	13.6	8.0
Mechanical injury (human caused)	35.7	25.0	9.4
Bronze poplar borer (*Agrilus liragus*)	35.7	16.3	6.5
Black canker (*Ceratocystis fimbriata*)	28.6	15.2	3.6
Cytospora canker (*Cytospora chrysosperma*)	21.4	17.2	3.6
Fire	7.1	38.4	3.6

BLM plot summary: Frequency of secondary damage agents for aspen stems > 2" dbh (n=14)

Alturas, Eagle Lake and Surprise Field Offices			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Mechanical injury (unknown origin)	64.3	19.8	14.5
Sooty-bark canker (*Encoelia pruinosa*)	57.1	18.3	10.9
Sapsucker (*Sphyrapicus* spp.)	50.0	19.0	11.6
Canker (not identified)	50.0	16.7	9.4
Mechanical injury (human caused)	42.9	14.5	5.8
Cytospora canker (*Cytospora chrysosperma*)	42.9	12.1	5.8
Bronze poplar borer (*Agrilus liragus*)	42.9	8.4	4.3
Woodborer (not identified)	35.7	17.5	7.2
Hypoxylon canker (*Hypoxylon mammatum*)	28.6	14.0	5.1
Star gallery insect (not identified; bark beetle)	28.6	13.5	3.6

BLM plot summary: Frequency of primary and secondary/tertiary damage agents for aspen sprouts (n=14)

Alturas, Eagle Lake and Surprise Field Offices	
Primary agents	% of all aspen sprouts
Animal browsing (wild and domestic ungulates)	29.9
Mechanical injury (unknown origin)	17.2
Leafhoppers (various species)	6.2
Aspen leaf tier (*Sciaphila duplex*)	5.7
Secondary/Tertiary agents	% of all aspen sprouts
Marssonina leaf spot (*Marssonina populi*)	27.5
Mechanical injury (unknown origin)	25.1
Leafhoppers (various species)	17.1
Ink spot (*Ciborinia whetzelii*)	15.2

Lassen National Forest (LNF)

LNF plot summary: Aspen density, size class, mortality and percent crown dieback (n=25)

Almanor, Eagle Lake and Hat Creek Ranger Districts			
	Mean	StDev	Range
Elevation (ft)	5653	514	4603 - 6869
Live aspen ≥ 5.0” dbh (trees)	8.0	5.3	2 - 26
Live aspen 2.0 - 4.9” dbh (saplings)	2.8	4.7	0 - 18
Live aspen < 2.0” dbh (sprouts)	37.6	55.6	0 - 240
Dead aspen ≥ 5.0” dbh	0.7	1.2	0 - 4
Dead aspen 2.0 - 4.9” dbh	0.04	0.2	0 - 1
Dead aspen < 2.0” dbh	2.9	5.4	0 - 26
% dead stems/plot	8.8	11.0	0 - 36
% aspen > 2.0” dbh with no dieback	0	0	0
% aspen > 2.0” dbh with light dieback	45.3	32.5	0 - 100
% aspen > 2.0” dbh with moderate dieback	38.0	29.4	0 - 100
% aspen > 2.0” dbh with severe dieback	16.8	24.2	0 - 100
Sprouts/acre	3764	5564	0 - 24000
% of plots with sprouts	88.0		

LNF plot summary: Frequency of primary damage agents for aspen stems > 2” dbh (n=25)

Almanor, Eagle Lake and Hat Creek Ranger Districts			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Mechanical injury (unknown origin)	84.0	24.2	22.2
Sapsucker (*Sphyrapicus* spp.)	60.0	38.5	26.4
Frost	32.0	12.8	3.9
Sooty-bark canker (*Encoelia pruinosa*)	28.0	15.0	5.6
Bronze poplar borer (*Agrilus liragus*)	28.0	10.6	3.2
Black canker (*Ceratocystis fimbriata*)	24.0	19.5	5.3
Mechanical injury (human caused)	24.0	17.7	4.9
Aspen gall disease (*Diplodia tumefaciens*)	20.0	27.8	7.0
Poplar-gall Saperda (*Saperda* spp.)	16.0	13.2	4.2
Canker (not identified)	16.0	9.0	2.1

LNF plot summary: Frequency of secondary damage agents for aspen stems > 2” dbh (n=25)

Almanor, Eagle Lake and Hat Creek Ranger Districts			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Mechanical injury (unknown origin)	64.0	19.2	15.1
Sapsucker (*Sphyrapicus* spp.)	56.0	15.6	9.5
Canker (not identified)	52.0	14.1	8.5
Frost	40.0	14.9	4.9
Bronze poplar borer (*Agrilus liragus*)	32.0	9.8	4.2
Sooty-bark canker (*Encoelia pruinosa*)	24.0	12.9	3.2
Cytospora canker (*Cytospora chrysosperma*)	20.0	16.4	3.2
Leafhoppers (various species)	20.0	9.9	2.8
Large aspen tortrix (*Choristoneura conflictana*)	20.0	8.2	2.8
Black canker (*Ceratocystis fimbriata*)	16.0	19.5	2.8

LNF plot summary: Frequency of primary and secondary/tertiary damage agents for aspen sprouts (n=25)

Almanor, Eagle Lake and Hat Creek Ranger Districts	
Primary agents	% of all aspen sprouts
Animal browsing (wild and domestic ungulates)	37.3
Marssonina leaf spot (*Marssonina populi*)	23.3
Mechanical injury (unknown origin)	7.8
Leafhoppers (various species)	5.4
Secondary/Tertiary agents	% of all aspen sprouts
Ink spot (*Ciborinia whetzelii*)	13.5
Animal trampling (large ungulate)	7.1
Marssonina leaf spot (*Marssonina populi*)	5.0
Cynipid galls (Family: Cynipidae)	4.9

Modoc National Forest (MDF)

MDF plot summary: Aspen density, size class, mortality and percent crown dieback (n=22)

Big Valley, Devils Garden, Doublehead and Warner Mountain Ranger Districts			
	Mean	StDev	Range
Elevation (ft)	5752	940	4235 - 7120
Live aspen ≥ 5.0” dbh (trees)	8.4	3.8	2 - 19
Live aspen 2.0 - 4.9” dbh (saplings)	1.4	1.8	0 - 6
Live aspen < 2.0” dbh (sprouts)	21.6	13.0	0 - 42
Dead aspen ≥ 5.0” dbh	1.0	1.1	0 - 3
Dead aspen 2.0 - 4.9” dbh	0.1	0.5	0 - 2
Dead aspen < 2.0” dbh	4.2	6.8	0 - 20
% dead stems/plot	13.3	13.9	0 - 50
% aspen > 2.0” dbh with no dieback	0	0	0
% aspen > 2.0” dbh with light dieback	32.8	26.9	0 - 82
% aspen > 2.0” dbh with moderate dieback	42.5	19.9	0 - 80
% aspen > 2.0” dbh with severe dieback	24.7	23.5	0 - 86
Sprouts/acre	2164	1296	0 - 4200
% of plots with sprouts	90.9		

MDF plot summary: Frequency of primary damage agents for aspen stems > 2" dbh (n=22)

Big Valley, Devils Garden, Doublehead and Warner Mountain Ranger Districts			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Sapsucker (*Sphyrapicus* spp.)	68.2	36.7	27.1
Mechanical injury (unknown origin)	63.6	22.0	15.8
Aspen gall disease (*Diplodia tumefaciens*)	40.9	17.6	7.9
Sooty-bark canker (*Encoelia pruinosa*)	36.4	10.8	4.6
Bronze poplar borer (*Agrilus liragus*)	36.4	9.9	3.8
Hypoxylon canker (*Hypoxylon mammatum*)	27.3	26.9	8.8
Canker (not identified)	27.3	8.6	2.9
Snake canker (*Cryptosphaeria populina*)	22.7	11.7	2.9
Black canker (*Ceratocystis fimbriata*)	18.2	26.8	4.6
Poplar borer (*Saperda calcarata*)	13.6	18.9	2.9

MDF plot summary: Frequency of secondary damage agents for aspen stems > 2" dbh (n=22)

Big Valley, Devils Garden, Doublehead and Warner Mountain Ranger Districts			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Sapsucker (*Sphyrapicus* spp.)	77.3	18.8	15.0
Mechanical injury (unknown origin)	68.2	22.9	16.3
Canker (not identified)	50.0	12.1	6.3
Aspen gall disease (*Diplodia tumefaciens*)	45.5	17.2	9.2
Bronze poplar borer (*Agrilus liragus*)	36.4	16.7	6.3
Sooty-bark canker (*Encoelia pruinosa*)	36.4	9.5	3.8
Woodborer (not identified)	31.8	13.6	5.0
Poplar borer (*Saperda calcarata*)	27.3	14.1	4.2
Star gallery insect (not identified; bark beetle)	22.7	15.3	4.6
Large aspen tortrix (*Choristoneura conflictana*)	18.2	16.9	4.2

MDF plot summary: Frequency of primary and secondary/tertiary damage agents for aspen sprouts (n=22)

Big Valley, Devils Garden, Doublehead and Warner Mountain Ranger Districts	
Primary agents	% of all aspen sprouts
Animal browsing (wild and domestic ungulates)	45.6
Ink spot (*Ciborinia whetzelii*)	12.4
Marssonina leaf spot (*Marssonina populi*)	5.6
Large aspen tortrix (*Choristoneura conflictana*)	5.2
Secondary/Tertiary agents	% of all aspen sprouts
Leafhoppers (various species)	11.1
Marssonina leaf spot (*Marssonina populi*)	10.7
Animal browsing (wild and domestic ungulates)	10.6
Ink spot (*Ciborinia whetzelii*)	8.4

Plumas National Forest (PNF)

PNF plot summary: Aspen density, size class, mortality and percent crown dieback (n=17)

Beckwourth, Feather River and Mt. Hough Ranger Districts			
	Mean	StDev	Range
Elevation (ft)	6132	416	5457 - 6970
Live aspen ≥ 5.0" dbh (trees)	12.1	7.8	2 - 29
Live aspen 2.0 - 4.9" dbh (saplings)	2.4	3.6	0 - 12
Live aspen < 2.0" dbh (sprouts)	35.4	27.7	2 - 96
Dead aspen ≥ 5.0" dbh	1.2	2.0	0 - 7
Dead aspen 2.0 - 4.9" dbh	0.1	0.2	0 - 1
Dead aspen < 2.0" dbh	2.6	5.9	0 - 24
% dead stems/plot	7.2	12.4	0 - 47
% aspen > 2.0" dbh with no dieback	0	0	0
% aspen > 2.0" dbh with light dieback	57.2	25.0	25 - 100
% aspen > 2.0" dbh with moderate dieback	31.6	19.0	0 - 63
% aspen > 2.0" dbh with severe dieback	11.2	13.4	0 - 47
Sprouts/acre	3541	2768	200 - 9600
% of plots with sprouts	100.0		

PNF plot summary: Frequency of primary damage agents for aspen stems > 2" dbh (n=17)

Beckwourth, Feather River and Mt. Hough Ranger Districts			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Sapsucker (*Sphyrapicus* spp.)	82.4	27.4	23.6
Mechanical injury (unknown origin)	82.4	26.9	24.7
Bronze poplar borer (*Agrilus liragus*)	41.2	10.3	4.5
Aspen gall disease (*Diplodia tumefaciens*)	41.2	10.1	5.2
Sooty-bark canker (*Encoelia pruinosa*)	29.4	19.2	5.6
Mechanical injury (human caused)	29.4	10.7	5.2
Black canker (*Ceratocystis fimbriata*)	23.5	7.8	2.2
Fire	17.6	35.0	5.2
Animal clawing (bear)	17.6	12.1	3.0
Hypoxylon canker (*Hypoxylon mammatum*)	11.8	25.0	5.6

PNF plot summary: Frequency of secondary damage agents for aspen stems > 2" dbh (n=17)

Beckwourth, Feather River and Mt. Hough Ranger Districts			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Mechanical injury (unknown origin)	70.6	23.7	21.3
Sapsucker (*Sphyrapicus* spp.)	64.7	19.0	15.0
Aspen gall disease (*Diplodia tumefaciens*)	64.7	7.4	4.5
Mechanical injury (human caused)	47.1	16.3	7.5
Bronze poplar borer (*Agrilus liragus*)	41.2	10.3	5.2
Animal clawing (bear)	35.3	15.6	5.2
Poplar branch borer (*Oberea schaumii*)	29.4	14.4	5.2
Sooty-bark canker (*Encoelia pruinosa*)	29.4	9.3	3.7
Large aspen tortrix (*Choristoneura conflictana*)	23.5	12.1	3.0
Fire	23.5	7.9	2.6

PNF plot summary: Frequency of primary and secondary/tertiary damage agents for aspen sprouts (n=17)

Beckwourth, Feather River and Mt. Hough Ranger Districts	
Primary agents	% of all aspen sprouts
Animal browsing (wild and domestic ungulates)	29.4
Shoot blight (*Venturia tremulae*)	24.9
Marssonina leaf spot (*Marssonina populi*)	10.8
Animal trampling (large ungulate)	10.3
Secondary/Tertiary agents	% of all aspen sprouts
Animal browsing (wild and domestic ungulates)	18.4
Caterpillar feeding (various species)	12.5
Poplar aphid (not identified)	10.3
Mechanical injury (unknown origin)	9.1

Tahoe National Forest (TNF)

TNF plot summary: Aspen density, size class, mortality and percent crown dieback (n=13)

American River, Sierraville, Truckee and Yuba River Ranger Districts			
	Mean	StDev	Range
Elevation (ft)	6393	441	5629 - 7437
Live aspen ≥ 5.0” dbh (trees)	10.9	7.7	3 - 26
Live aspen 2.0 - 4.9” dbh (saplings)	2.0	3.0	0 - 11
Live aspen < 2.0” dbh (sprouts)	59.4	60.9	0 - 205
Dead aspen ≥ 5.0” dbh	1.1	2.3	0 - 8
Dead aspen 2.0 - 4.9” dbh	0.2	0.4	0 - 1
Dead aspen < 2.0” dbh	1.3	2.3	0 - 8
% dead stems/plot	6.6	7.5	0 - 22
% aspen > 2.0” dbh with no dieback	0	0	0
% aspen > 2.0” dbh with light dieback	46.3	28.7	0 - 77
% aspen > 2.0” dbh with moderate dieback	41.9	23.3	11 - 80
% aspen > 2.0” dbh with severe dieback	11.9	17.4	0 - 50
Sprouts/acre	5938	6087	200 - 20500
% of plots with sprouts	100.0		

TNF plot summary: Frequency of primary damage agents for aspen stems > 2” dbh (n=13)

American River, Sierraville, Truckee and Yuba River Ranger Districts			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Mechanical injury (unknown origin)	92.3	32.4	31.9
Sapsucker (*Sphyrapicus* spp.)	92.3	21.4	21.1
Bronze poplar borer (*Agrilus liragus*)	46.2	18.7	9.2
Aspen gall disease (*Diplodia tumefaciens*)	46.2	5.9	3.8
Rough bark disease (*Rhytidiella baranyayi*)	30.8	19.0	8.1
Woodborer (not identified)	30.8	4.8	2.7
Mechanical injury (human caused)	23.1	10.7	3.2
Sooty-bark canker (*Encoelia pruinosa*)	23.1	9.9	4.3
Hypoxylon canker (*Hypoxylon mammatum*)	23.1	8.6	3.2

TNF plot summary: Frequency of secondary damage agents for aspen stems > 2" dbh (n=13)

American River, Sierraville, Truckee and Yuba River Ranger Districts			
	% positive plots	% affected stems on positive plots	% affected stems on all plots
Sapsucker (*Sphyrapicus* spp.)	76.9	15.0	11.4
Mechanical injury (unknown origin)	76.9	11.0	9.2
Bronze poplar borer (*Agrilus liragus*)	61.5	15.7	10.3
Sooty-bark canker (*Encoelia pruinosa*)	46.2	9.8	4.3
Aspen gall disease (*Diplodia tumefaciens*)	38.5	16.7	8.6
Rough bark disease (*Rhytidiella baranyayi*)	38.5	14.3	7.6
Canker (not identified)	38.5	10.5	4.9
Poplar branch borer (*Oberea schaumii*)	23.1	23.3	5.4
Hypoxylon canker (*Hypoxylon mammatum*)	23.1	12.9	4.3
Animal clawing (bear)	15.4	22.9	4.3

TNF plot summary: Frequency of primary and secondary/tertiary damage agents for aspen sprouts (n=13)

American River, Sierraville, Truckee and Yuba River Ranger Districts	
Primary agents	% of all aspen sprouts
Animal browsing (wild and domestic ungulates)	37.5
Shoot blight (*Venturia tremulae*)	24.5
Animal trampling (large ungulate)	4.9
Leafhoppers (various species)	4.7
Secondary/Tertiary agents	% of all aspen sprouts
Marssonina leaf spot (*Marssonina populi*)	16.4
Mechanical injury (unknown origin)	8.9
Animal trampling (large ungulate)	7.9
Ink spot (*Ciborinia whetzelii*)	7.4